grading governs extent to which lower edge of upper bank grading may be carried. It is desirable that it extend down to low water line. Explosives may be utilized to assist in grading, but care must be employed in their use.

Underwater slopes should not be steeper that 1 to 1; indeed it is difficult to hold successfully any slope steeper than 3 to 1. Where steep underwater slopes exist, it is sometimes advisable to sink only the subaqueous mat. Subsequent action of river currents may then cause further recession of bank, but the subaqueous mat, though partially lost, remains as a heel to establish the foot of the slope which will gradually, by placing of later successive mats, assume a slope which can be held successfully.

Water pocketed upon the bank in old levee borrow pits, ditches, or depressions may, when overbank river stages recede, seep through underlying strata of bank and accelerate caving. Accordingly drainage ditches are constructed into the river from all depressions within 300 feet of the top of bank line, and frequently from farther distant pools. These ditches must be paved for a short distance at their riverside ends to prevent scours from draining waters; this ditch paving must be firmly connected with upper bank paving to prevent failure along connection.

Considerable trouble results from underground seepage from lakebeds lying to the landside of controlling levees. Proper drainage from such sources is much more difficult than in the case noted above concerning riverside pools; special study is necessary for each locality, and in some instances the problem is as yet without solution.

Bank Grading Operations—Bank grading is usually performed by hydraulic graders. These hydraulic graders in the Vicksburg district consist of a barge on which is mounted two multiple stage centrifugal pumps, driven by steam turbines, which pump river water at 250 lbs. per sq. in. pressure through 5-in. pipe lines to 1¼-in nozzles (1$\frac{1}{16}$-in. for sandy bank). These nozzles operating on the bank are utilized to undercut the bank material and slope off the bank to the desired 4 to 1 slope. The dual unit (boiler, turbine, and pump) exists on each grader. Each pump operates one nozzle. Four-inch rubber sections provide a flexible connection between pipe and nozzle. All pipe sections are connected by flexible Moran type ball and socket joints. The second

story of the cabin erected on each grader provides living and messing facilities for the necessary operating personnel. Three of these hydraulic graders operate in the Vicksburg Engineer District.

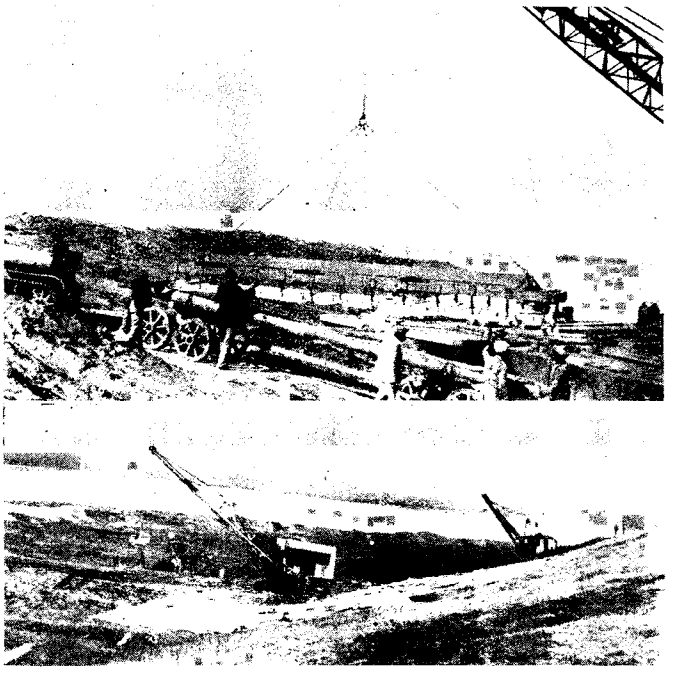


FIG. 7—PAVING SCOURED LEVEE WITH MAT SECTIONS. HAULING BY TRACTOR AND WAGON

FIG. 8—PAVING SCOURED LEVEE WITH MAT SECTIONS

An experimental mechanical bank grader was erected and operated in the Vicksburg Engineer district during the 1929 season. This mechanical grader consists of a revolving, levee-building steam dragline mounted on two standard steel barges placed side by side and firmly connected. The machine was originally constructed to handle a 5 cu. yd. bucket on a 165 ft. boom. The boom has been shortened to 150 ft. and reinforced. Instead of the dragline bucket, earth is moved by a curved scraper placed at the end of two dipper sticks. The dipper sticks remain

in a nearly vertical position during the earth moving operation, sliding up and down in guides on a traveling cradle which moves in and out along the lower members of the boom. A dragline

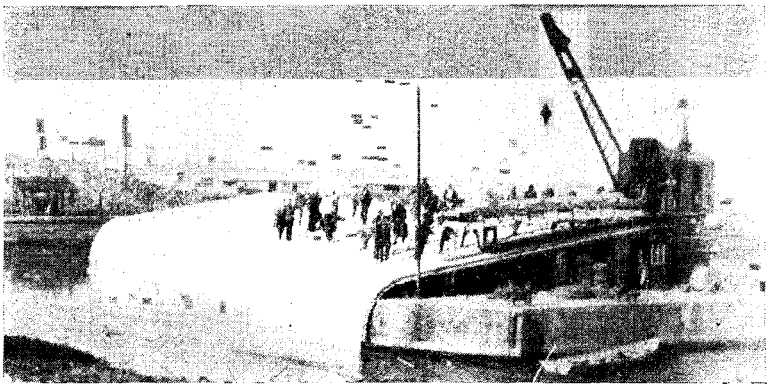


FIG. 9—PAVING UPPER BANK WITH FLOATING LOCOMOTIVE CRANE
FIG. 10—ASSEMBLING MAT SECTIONS, SINKING BARGE (25 SQUARE LAUNCH)

pulls the scraper-head toward the machine; a backhaul cable pulls it toward the top of the bank; two lines govern the travel of the cradle along the boom, while a fifth line regulates the elevation of the scraper-head and slides the attached dipper

sticks through the guides on the cradle. The entire machine may be revolved on its turntable or self-propelled on its rail track along the barges. Two operators are required to manipulate the numerous controls.

The machine operates with the long dimension of its supporting barges parallel to the bank line. Mooring barges, headed into the

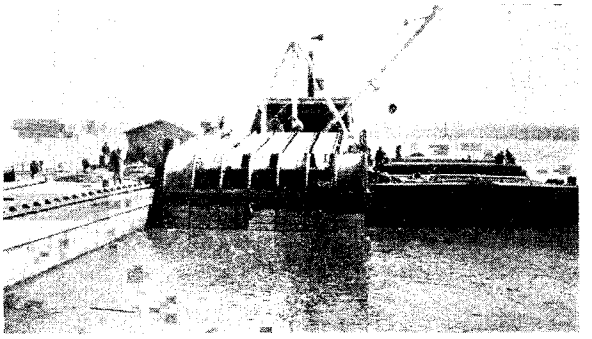
FIG. 11—PAVING UPPER BANK SHOWING MAT-LIFTING FRAME AND GRAPPLE HOOKS

FIG. 12—PAVING UPPER BANK WITH DERRICK BOAT

bank, are placed against the supporting barges, above and below. The machine and its supporting barges may thus be moved to and from the bank between the mooring barges.

This machine grades 12 ft. below water surface. Following preliminary experimental operation at the beginning of the season, and with acquisition of experience in handling by oper-

ators, the machine can well be considered a success. The absence of water renders its use desirable on sloughing banks; its costs during the latter part of the season were lower than those of hydraulic graders; it accomplishes underwater grading; on repair work on short stretches of bank it is much more economical since its mobilization and demobilization is far simpler.



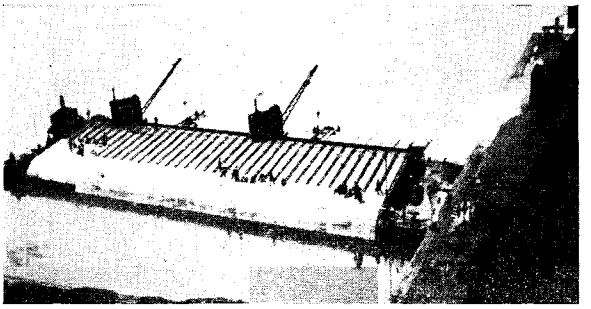


FIG. 13—END CONNECTING MAT BOAT
FIG. 14—LARGE MAT SINKING BARGE (35 SQUARE LAUNCH)

It has the disadvantage of much higher first cost. Contemplated improvements in future design embrace lowering of entire machine nearer to deck of supporting barges; lowering of dragline sheave; installation of mechanical devices for moving in and out along mooring barges instead of present manual operation; utilization of Diesel or Diesel-electric power.

Subaqueous Mat—Subaqueous articulated type reinforced

concrete revetment used in the Vicksburg Engineer district consists of standard articulated mat sections having their outside longitudinal reinforcing wires securely fastened to a standard steel anchoring cable. This fastening consists of clips (U-bolts, bridge and two nuts, all with japanned finish) set at intervals not greater than 5 ft.; each clip encloses in its grip the outside longitudinal reinforcing wires of adjacent mat sections together with the included anchoring cable.

An additional fastening, including the same reinforcing wires and anchoring cable as the clips, is placed at one foot intervals between the clips; this additional fastening consists of a galvanized wire of No. 12 gage, doubled and tightly twisted.

Anchoring cable consists of 7/16 in. or 1/2 in. standard galvanized steel cable having breaking strengths, respectively, of 9,000 to 10,000 lbs. and 14,000 to 15,000 lbs. The size of anchoring cable used depends on depth of river, steepness of underwater slope, and velocity of current in the locality of construction. Normally upstream five cables of each mat are 1/2 in. the remainder 7/16 in.

Each anchoring cable is securely fastened to an anchorage consisting of a deadman, sound stump, or other secure anchorage. These anchorages exist or are placed at least 10 ft. inshore from the upper edge of the graded bank, and must develop a resistance not less than twice the combined ultimate strength of attached anchoring cables. Anchoring cables may not deviate more than 2 ft. from a straight line from the mat fastening to the anchorage. Not more than two adjacent cables are fastened to any one anchorage.

Subaqueous mat is assembled prior to launching. The mat sections are placed with 25 ft. dimensions approximately perpendicular to top of bank line. Any number of mat sections up to capacity of the mat placing barge, may assemble adjacent to each other; a portion of mat so assembled is termed a "launch." Successive launchings must be continuous from waters-edge to deepest water; this continuity is secured by the clip fastenings to anchoring cables and by twisting tightly together the wire loops in the end blocks of contiguous and abutting mat sections of successive launchings.

A continuous series of successive "launches" from waters-edge

to deepest water is called a "mat." Work is normally begun at downstream end of the proposed revetment. Successive mats are overlapped a minimum of ten feet, the upstream mat overlapping the next downstream mat. Overturning of upper edges of mat by the current is thus prevented.

Upper Bank Paving consists of that portion of the revetment extending from top-of-paving-line to the upper edge of the subaqueous mat. The top-of-paving-line is an elevation or contour representing the average top-of-bank-line or limiting line designated for protection in a given locality; it is usually expressed in terms of an elevation on the nearest United States Engineer Department river gage.

The upper bank paving may consist of:

a. Monolithic reinforced concrete.

b. Standard reinforced concrete mat sections.

c. Concrete blocks.

d. Riprap stone.

The last two named are laid by hand. Only the first two were used in the Vicksburg District during the 1929 season; the following descriptions will be limited to these first two types.

Monolithic concrete paving—Monolithic upper bank paving consists of a sheet of reinforced concrete with minimum thickness of 4 in.; 2000 lb. concrete is used. A reinforcing mesh is used similar to that for mat sections.

The concrete is brought to a reasonably smooth surface. The reinforcement is finally imbedded, and may not be closer than ½ in. to the upper surface of the concrete. Adjacent sections of reinforcement are overlapped at least 6 in. Expansion joints are provided. Monolithic paving is not placed at temperatures below 40° F.

Anchoring cables of the subaqueous mat are firmly imbedded in the monolithic paving.

An anchoring curb is constructed along the top-of-paving-line by digging a trench whose minimum dimensions are 4 in. wide and 18 in. deep. The reinforcing mesh of the paving is turned

down into this trench and both paving and curb are poured simultaneously.

Paving with mat sections—As nearly as practicable, bank paving with mat sections is merely a continuation of the subaqueous mat up to the top-of-paving-line. Wherever possible, anchorage cables of the subaqueous mat are included in the fastenings of the sections of the upper bank paving; except where it is thus possible to include anchoring cables, clips are omitted and all fastenings are made of twisted wires only. The 25 ft. dimension is always placed perpendicular to the top-of-paving-line.

A variation extensively used this past season consists of laying upper bank mat sections from waters-edge up, overlapping by two blocks the upper section over the next lower, rather than butting the ends. This method gives a stronger job and obviates construction difficulties occasioned by attempting to fit ends of sections where the bank contours are irregular.

When it becomes necessary to overlap adjacent mat sections laterally, the upstream section overlaps the downstream square.

CONNECTIONS

Connecting Mats—The most desirable condition for construction of revetment exists where it is possible to complete grading at a low river stage, place subaqueous mat at nearly bankfull stage, and complete upper bank paving at a medium stage. Such ideal conditions rarely follow in sequence. It is unfortunately oftener necessary to place subaqueous work at a low stage and complete upper bank paving at a higher stage.

When this latter condition obtains, it is necessary to construct a "connection" from the subaqueous mat to an elevation slightly above waters-edge. Such connection consists of a "connecting mat" which overlaps the subaqueous mat at least 10 ft. and not more than 15 ft.

Connection between monolithic upper bank paving and subaqueous or connecting mat is performed, in the dry, by extending the reinforcement of the monolithic paving down over the lower mat sections for an overlap of 6 ft. Standard monolithic concrete is then poured to a thickness of 2 in. above the mat sections of the lower mat. The consistency of this concrete and the work-

manship involved in its placing are such as thoroughly to imbed the anchoring cables, exterior reinforcing wires and interstices of the mat sections, as well as the overlapping reinforcement of the upper bank paving. The concrete of the connection is poured practically simultaneously with and thoroughly bonded to the concrete of the upper bank paving.

PLANT AND EQUIPMENT

The following special equipment is used in concrete revetment construction in the Vicksburg District.

Mat placing barges
Upper and lower mooring barges
End connecting mat barge
Tower paving barge
Locomotive crane barges
Derrick barges

A brief description of each special type follows:

Mat Placing Barges—During the 1929 season two mat placing barges were used. The older and larger of the two permits the construction of a 35-sq. launch; this barge is steam powered. The squares are transferred from a loaded casting barge lashed to the outside of the mat placing barge by two locomotive cranes to the sloping deck of the placing barge. Each mat section rests on two parallel rows of rollers. Anchoring cables run from reels placed under the construction ways and are led back and interlaced through two friction pulleys, through the upper deck, down between adjacent mat sections and over the inside curved edge of the placing barge. A steam winch drives the pay-off mechanism through a long shaft and train of gears. The gear train is so arranged that mat may be paid off in any one or combination of five 7 square sections, or as a 35 square unit. Steam capstans on each end of the placing barge provide power for moving the placing barge along the lower mooring barges.

The smaller placing barge provides for a launch of 25 squares. A single steam locomotive crane is installed. All other power is secured from individual gasoline-engined units. The inner (shoreward) side is constructed with a longer overhanging rake, which places upper edge of mat nearer to waters-edge than does large placing barge.

Both of the above barges are of steel construction throughout.

Lower Mooring Barges—These barges (360 ft. total length) are of steel for the large plant and of wood for the smaller. Along the downstream edge there is a track along which a heavy trolley runs. The placing barge is lashed to this trolley.

Six steam winches placed at intervals along the lower mooring barges furnish power for drawing the mooring barges and attached placing barge upstream for sinking successive mats. Each winch is equipped with 1200 ft. of steel cable which is led out through a "rooster-head" fairlead to fastenings on the upper mooring barges.

Upper Mooring Barges—The upper mooring barges (240 ft. total length) serve as a spread anchorage for the cables from the lower mooring barges, and are in turn fastened to shore anchorages above. They are of wood for the small plant, and of steel for the large plant.

End Connecting Mat Barge—In order to place connecting mats with upper edge above the waters-edge, the mat launches are paid off over the end of the connecting mat barge whose rake, for the first launch, overhangs the bank. The present barge is of wood, and provides for a launch of 7 squares. A stiffleg derrick transfers mat sections to the construction platform.

Tower Paving Barge—This barge (Fig. 15) is of special size and of steel construction. An Insley Tower, with chute and counter-weighted distributing trussed chute distributes concrete for monolithic bank paving. A skiphoist conveys the concrete to the chute from a 1-yd. mixer. Sand and gravel hopper is equipped with weighing batchers. Cement is measured by the sack, and is conveyed to the mixer by ladder conveyor from a cement storage house. A stiffleg derrick loads sand and gravel from an attached barge to the hopper. Steam power is utilized throughout.

The maximum output attained by this plant during the past season (and during its use) was 275 squares of standard monolithic paving in ten hours. Its average output is 200 squares per day.

Locomotive Crane Barges—Locomotive crane barges consist of a steam railway locomotive crane with 65-ft. boom on a standard sized steel barge. Special interior bracing is built into the barge. These units are utilized in placing mat sections on